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**PATENT APPLICATION NUMBER 9915925.3**

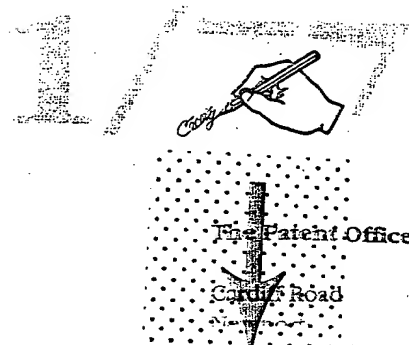
The Patent Office confirms receipt of a request for grant of a patent, details of which have been recorded as follows :

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Applicants	: Loughborough University Innovations Limited
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Patents ADP number (if you know it)

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4. Title of the invention

Flow Field Plates

5. Name of your agent (if you have one)

"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)

McNeight & Lawrence  
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Stockport, Cheshire SK4 1BS

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### **Flow Field Plates**

This invention relates to flow field plates and the manufacture thereof, for use in fuel cells, electrolyzers, and batteries which contain a fluid electrolyte.

A fuel cell is an electrochemical device in which chemical energy is converted directly into electrical energy. Fuel cells employ electrodes, comprising an anode and a cathode, electrocatalysts, often supported on the electrodes, and an electrolyte. A fuel and an oxidant are separately supplied to the anode and cathode, respectively.

Solid Polymer Fuel cells (SPFC) employ a membrane electrode assembly (MEA), consisting of a solid polymer electrolyte with impressed electrocatalyst layers sandwiched between two electrically conductive plates which have a fluid flow field to distribute the fuel and oxidant across the active area of the electrodes. These flow field plates, also known as current collector plates or bipolar plates, may additionally provide mechanical support for the MEA. Fluid galleries are formed in the faces of the flow field plates to direct fuel and oxidant, respectively, into the fluid flow field. Fluid exit galleries in the flow field plates allow for removal of unreacted fuel and oxidant as well as reaction product (e.g. water in an oxygen/hydrogen fuel cell) formed at the cathode.

Performance of fuel cells is partly dependent on the efficient supply of fuel and oxidant to the electrodes and also the efficient removal of reaction product during functioning of the cell. The design and manufacture of flow fields on flow field plates is thus an important consideration for optimal fuel cell operation.

For most applications, fuel cells may be connected in series to form a "stack" so that voltage output is increased. The flow field plates between cells may be bipolar such that fuel and oxidant are distributed separately through flow fields on opposite faces of the plate. In stacks, flow field plates should be impermeable to reactants to prevent crossover between adjacent cells.

Flow field plates used in fuel cell stacks have been constructed from several types of material. This material requires the following properties:

- (i) chemical compatibility with electrolytes;
- (ii) low resistivity (contact and bulk) to reduce power loss;
- (iii) impermeability to  $H_2$  and  $O_2$ ;
- (iv) allows for easy manufacture of plates;
- (v) light in weight; and
- (vi) sufficient strength to withstand handling and high compaction pressures.

Carbon-based flow field plates have been reported for use in low temperature fuel cells, particularly SPFCs. Carbon is an excellent material for this application, possessing excellent chemical resistance, low density and high electronic and thermal conductivity.

Press-moulding has been used to fabricate a flow field plate, complete with embossed fluid flow design thereon, from exfoliated graphite. For example, a flow field plate manufactured from a fine grained graphite (GRAFOIL®) is provided in US 5 521 018.

US 4 301 222 and EP 784 352 describe the use of resins to form plates with improved mechanical strength, but these insulating resins may reduce the overall conductivity of such plates and result in increased losses in fuel cell stacks. In another invention, US 4 339 322, carbon fibres have been added to a polymer/graphite material to enhance plate strength and conductivity. However, resistivities of the plates disclosed in US 4 339 322 are significantly higher than plate manufactured only from graphite.

As described in US 5 686 199, it is possible to machine fine grained graphite plates to form fluid flow patterns. Due to low mechanical strength of the material, however, these plates are often unacceptably thick. Also, the machining of fluid flow fields on carbon plates is a slow process and tool wear is rapid with this material. Carbon fibre composite materials are even more abrasive and more damaging to cutting tools than standard carbon material. These material have been avoided due to the costly specialised equipment employed.

Current technology therefore does not provide a rapid, low cost process for the manufacture of flow field plates from desirable materials.

The technique of sand, bead, or grit blasting has been described previously for a few specified applications, such as signmaking and decorative patterning on stone, wood, ceramicware, plastic, glass and glass-reinforced plastic (e.g. US 4 828 893 and US 4 985 101), and surface cleaning or roughening treatments. Sandblasting has also been employed for forming plasma display apparatus (EP 0 722 179) and in the manufacture of magnetic transducing heads (US 4 188 247).

The present invention provides a novel, effective and improved method for the manufacture of electrochemical cell components such as the flow field plate. The

method employs a low cost and rapid erosive etch that allows formation of fluid flow patterns, fluid entry galleries and fluid exit galleries, and sealing grooves.

Thus according to the present invention, there is provided a method for the manufacture of flow field plates comprising particulate etching of plate material using a particulate etchant, a particulate etchant accelerator and a particulate etchant-resistant patterned mask, such that a fluid flow pattern determined by the pattern design on said mask is formed on said plate material.

Plate material for use in the present invention may comprise electrically conductive material. Such electrically conductive material may comprise carbon-based material. Furthermore, plate material may comprise carbon fibre composite material. This carbon fibre composite material may be densified with a polymeric filler, for example an epoxy resin. It has been found, surprisingly, that the rate of particulate etching of the carbon fibre and matrix in carbon fibre composite material does not differ, so the final structure of patterned grooves formed in this type of materials is not adversely affected.

The particulate etching may comprise sand blasting, and the particulate etchant accelerator may comprise a sandblasting gun. The particulate etching may also comprise grit blasting. Furthermore, the particulate etching may comprise abrasive waterjet blasting (also known as abrasive waterjet cutting). The invention requires that the particulate etchant contains an abrasive medium which has a greater hardness than that of the plate material to be etched. The particulate etchant may be silica grit with a diameter of 180-220  $\mu\text{m}$  for use against plate material which is a graphitised carbon-carbon composite material.

The procedure uses a particulate etchant-resistant mask which is patterned accordingly and which covers the face of the material to be etched. The mask may be composed of material that can withstand erosive wear caused by particulate etching. The mask should be in close proximity to the plate material to allow fine detailed patterns to be formed, so the mask may be held in contact with the plate material by means of an adhesive substance.

The particulate etchant-resistant patterned mask may be a photoresist mask. The technique of forming a photoresist mask is taught in, for example, US 4 764 449. In US 4 764 499, a negative mask of the required design is formed such that glass or wood exposed after adhesion of the mask is eroded by sandblasting.

The particulate etchant-resistant patterned mask may comprise a vinyl polymer. Here, a vinyl label is cut to shape to form a negative mask of the required pattern (see US 4 828 893).

The pattern design may determine a fluid entry gallery and a fluid exit gallery of the field flow plate. For example, a fluid entry gallery may be a fluid entry hole and a fluid exit gallery may be a fluid exit hole of the flow field plate. Certain etch resists could fail if galleries passing through the plate are etched through one face only. Therefore fluid entry galleries and fluid exit galleries may be formed by etching aligned positions on opposite faces of the flow field plate.

The pattern design may also determine grooves for seals on said flow field plate.

Particulate etching may be under the control of a two-axis scanning mechanism that determines movement of the particulate etchant accelerator relative to



the plate material. The two-axis scanning mechanism may enable a predetermined movement of the plate material relative to the particulate etchant accelerator such movement can be in the form of a raster pattern or a stepped scan pattern. A scanning mechanism will be particularly useful when the surface area of the plate material is approaching or greater than the spread of particulate from the particulate etchant accelerator.

Flow field plate manufactured according to the present invention may be incorporated in fuel cells, electrolyzers, and batteries which contain a fluid electrolyte. An electrolyzer, which is a means to decompose water into hydrogen and oxygen, is structurally very similar to a fuel cell.

The invention will be further apparent from the following description, with reference to the several figures of the accompanying drawings, which show, by way of example only, methods for the manufacture of field flow plates comprising different materials.

Of the Figures:

Figure 1 is a schematic side cross-sectional elevation illustrating the particulate etching method employed in the fabrication of fluid flow grooves on a bipolar flow field plate; and

Figure 2 is a schematic side cross-sectional elevation illustrating the particulate etching method employed in the fabrication of a fluid entry or exit hole in a flow field plate.

In Figure 1, a flow field plate 100 prepared for particulate etching comprises the plate material 3, and two opposite faces each layered with an adhesive 2 and 20 upon which the prepared particular etchant-resistant patterned masks 1 and 10 have been attached. The adhesive 2 and 20 must provide sufficient adhesion to hold the masks 1 and 10 firmly in place during the particulate etching process 6. Preferably, the adhesive 2 and 20 is water soluble so that the masks 1 and 10 can be easily removed from the plate material 3 after etching. The masks 1 and 10 may be mounted on a support film which is peeled away after the masks 1 and 10 have adhered to the adhesive 2 and 20.

Plate material 3 comprises carbon fibre composites, thereby possessing superior mechanical properties to monoliths, without loss of mechanical properties. The inclusion of carbon fibres can improve the thermal conductivity of plate material 3, which is an important feature if the downstream electrical application involves use of high current densities. Fabrication methods for typical carbon-carbon composite material are well known (See Thomas, C.R. [Editor], 1993, Essentials of carbon-carbon composites, Cambridge Royal Society of Chemistry Press, Cambridge, ISBN: 0851868045).

Use of high density carbon-carbon composites for plate material 3 is expensive, and partially densified materials may offer greater prospects. The gas permeability of partially densified plate material can be overcome by densification with a polymeric filler such as resin. The resin should preferably be of low viscosity to allow the rapid filling of small pores under low pressure, and should self-cure. The composition of the resin may be of any polymer formulation that will resist attack by an alkaline or acidic electrolyte. Immediately after the addition of a resin to plate material 3, unabsorbed resin should be removed from the surface of the plate 100. This can be carried out by wiping the plate 100 surface with an absorbent cloth. When the resin has been allowed to cure under the required conditions, surfaces on plate 100 required for

electrical conduction need to be cleaned to re-expose conductive carbon in plate material 3 . This can be achieved by a brief surface grinding step with an abrasive cloth with a mesh size of 600 or higher.

The particulate etchant-resistant patterned masks 1 and 10 have patterns 4 and 40 through which the plate material 3 will be etched. Pattern 4 on one face of plate material 3 is displaced relative to pattern 40 on the second face of plate material 3 so that a thin sheet of plate material 3 can be employed. Etching process 6 involves the exposure of the plate 100 to a particulate etchant (not shown) which is propelled by a particulate etchant accelerator (not shown) such as a sandblasting gun. The particulate etchant is any material which has a greater hardness than that of the plate material 3 to be etched. For carbonaceous materials (except diamonds), it is preferred that fine grained silica or alumina is used. The etchant size depends on the detail of the patterns 4 and 40 required on the plate 100.

The blasting pressure used in process 6 is dependent on masks 1 and 10, the adhesive 2 and 20, the distance between the etchant accelerator and the target surface of the plate material 3, and the etchant used. An upper pressure limit is given by the resistance to erosive etching of the masks 1 and 10, while a lower limit is defined by the pressure required to erode the material 3 with the abrasive etchant. The blasting pressure is optimal when substantial etching is produced within a reasonable time limit without damaging the masks 1 and 10 or causing the adhesive 2 and 20 to fail.

Etching process 6 is performed in two successive steps in which each face of plate 100 is etched. It is not ruled out, however, that the etching process 6 could be performed on both sides of plate 100 simultaneously using a plurality of particulate etchant accelerators.

During etching process 6, the target area of plate 100 is dependent on the spread of the etchant. This spread, in turn, is dependent on the distance of the particulate etchant accelerator from the surface of plate 100, and the dimensions of the particulate etchant accelerator nozzle (not shown). The plate 100 can be etched in a dynamic manner if the area of plate 100 is larger than the etchant spread. For example, the particulate etchant accelerator and plate 100 can be moved relative to each other using a two-axis scanning mechanism, in which either or both the accelerator and plate 100 are moved. The overall movement should provide uniform coverage of the plate 100 surface with the accelerated etchant.

After completion of etching process 6, the flow field plate 200 has a fluid flow field pattern 5 and 50 etched into the plate material 3 on both sides of the plate 200. The adhesive 2 and 20 and particulate etchant-resistant patterned mask 1 and 10 are then removed.

The fabrication of flow field plate holes for the entry or exit of fluids is illustrated in Figure 2. Preparation of flow field plate 300 requires the alignment of eroding grooves 7 and 70 patterned into the particulate etchant-resistant masks 1 and 10 on opposite faces of the plate material 3. The masks 1 and 10 are held firmly against the plate material 3 using an adhesive 2 and 20. Etching process 60 proceeds until a uniform opening 8 appears from one face of plate 400 through to the opposite face. Etching of both faces of plate material 3 to form the opening 8 is especially important where the material 3 would fail if etched from one face only.

The present invention will be further described by way of the following examples. The scope of the invention, however, is not limited in any way by these examples.

Example 1 (*Carbon-carbon composite plate + vinyl mask*):

A graphitised carbon-carbon composite plate of dimensions 50x50x1.2 mm was prepared with a gas track design on one face. A vinyl-polymer adhesive mask (FasCal Film [Avery, US]), with a negative image of the required gas track design, was pressed firmly onto the composite. A Guyson Blast System (Guyson, UK) with 180-220  $\mu\text{m}$  silica grit, was used to dry sandblasting the plate. The masked material was held under the sandblasting gun with a blast pressure set at 4 bar (400 kPa) for 30s, at a constant distance of 6'' (152.4 mm). The vinyl mask was then peeled off, and the adhesive washed off the plate using isopropyl alcohol. Track depth was 0.2-0.25 mm.

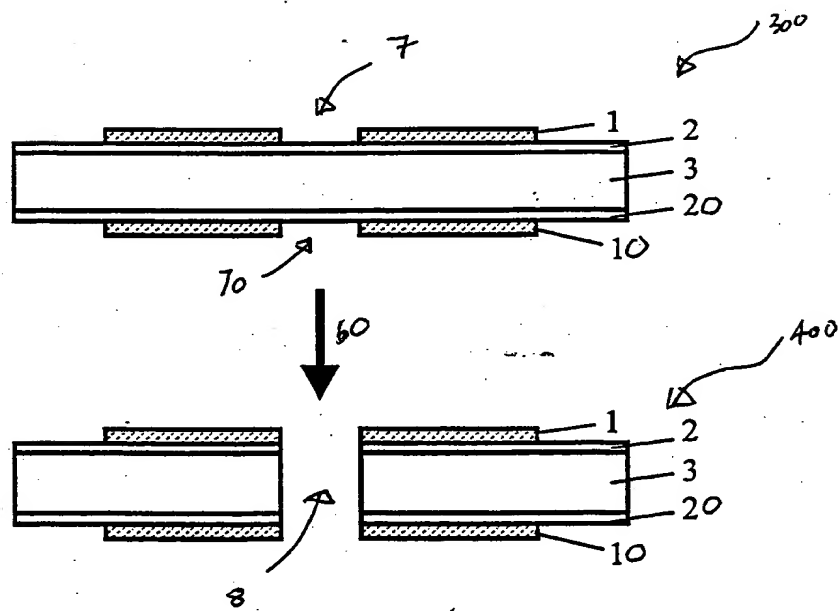
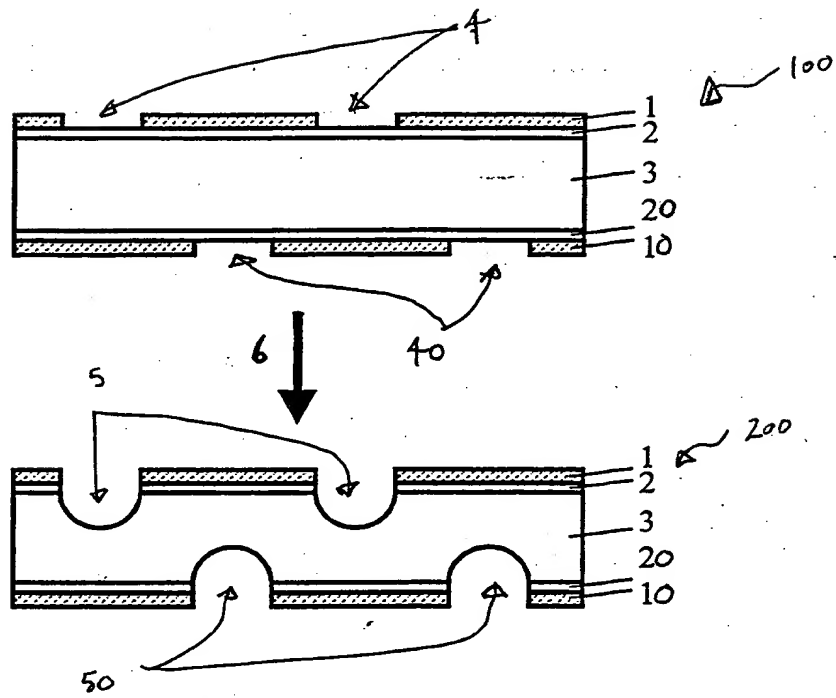
Example 2 (*Carbon-carbon composite plate + photoresist mask*):

A graphitised carbon-carbon composite plate of dimensions 50x50x1.2 mm was prepared with a gas track design on one face. A photoresist mask (ImagePro Super Film [Chromaline Corp., US]) was developed to form a negative template of the required gas track design. Using a photographic mask of the track design to cover the photoresist (with an underside protective carrier film) and a glass sheet to hold the sheets closely together, the film was exposed for 5 minutes to an 18 W UV light source, at a distance of 5 m. The film was then removed (under yellow light) and washed under running water for approximately 3 minutes in order to wash away unexposed resist. The resist film was dried in air, under normal lighting, to form the negative resist mask template. A liquid contact adhesive (ImagePro Adhesive [Chromaline Corp., US]) was brushed lightly over the composite plate surface, and allowed to dry in air for 10 minutes. The resist mask (with carrier film) was pressed onto the adhesive-covered plate, and the carrier film peeled away. The material was then blasted using the procedure described in Example 1 (*supra*). The resist mask was removed by dissolving the adhesive using warm running

water, thus revealing a flow field pattern etched into the carbon-carbon composite material.

Example 3 (*Carbon-carbon composite plate with epoxy resin + photoresist mask*):

A graphitised carbon-carbon composite plate of dimensions 50x50x1.2 mm was held under low pressure (preferably less than 10 mmHg [approximately 1.33 kPa], but up to 100 mmHg [approximately 13.3 kPa] feasible) impregnated with a low viscosity epoxy resin (SpeciFix-20 [Struers Ltd, UK]). Excess resin was removed from the surface of the plate using a paper towel. The plate was then allowed to stand in air, at standard temperature and pressure, for at least 8 hours to allow the resin to cure and harden. A photoresist mask (ImagePro Super Film) was prepared and then applied as in Example 2 (*supra*). The masked material was then blasted using the procedure described in Example 1 (*supra*). The resist mask was removed by dissolving the adhesive using warm running water.



2nd draft  
from Stuart  
P. Raman  
(2/6/99)

[Abstract]

### **Ceramic flow field plates**

This invention involves the fabrication of field flow plates using a sandblasting technique, through a mask of the desired gas flow pattern. This erosive process is a low cost, and rapid alternative to machining or etching techniques. The plates can be used in fuel cells, electrolyzers, or batteries which contain a flowing electrolyte. It can be applied to carbon materials, and other ceramics.



## TECHNICAL FIELD

The invention relates to the production of fuel cells, electrolyzers, and batteries which contain a flowing electrolyte, in particular the flow field plate component.

## DESCRIPTION

### *[Background]*

The fuel cell is an electrochemical device which converts chemical energy directly to electrical energy. Fuel cells are classified by the type of electrolyte, and their operating temperatures. An electrolyzer is effectively a means to decompose water into hydrogen and oxygen, and it is structurally very similar to a solid polymer fuel cell. The electrolytes are typically phosphoric acid (PAFC), molten carbonate (MCFC), solid oxide (SOFC), alkaline (AFC), or solid polymer (SPFC). Alkaline and solid polymer fuel cells are regarded as low operating temperature (below 100°C), and solid oxide high temperature (around 1000°C). The MCFC and PAFCs operate at intermediate temperatures. These fuel cells generally comprise of an anode and cathode with electrocatalysts, which are separated by an electrolyte. This is referred to as a membrane electrode assembly (MEA). A fuel and an oxidant are separately supplied to the anode and cathode, respectively. The cell is contained by two plates, which contain a gas flow field to distribute the fuel and oxidant across the active area of the electrodes.

For commercial applications fuel cells are connected in series, forming a 'stack', in order to increase the power output. The flow field plates between cells are bipolar, and distribute both the fuel and oxidant gases separately through on opposite sides of the plate.

Flow field plates, also referred to as electrode substrates, have the following additional functions:

- Highly conductive electrical connection between adjacent cells and to the voltage terminals.

- Mechanical support for the MEA.

Impermeable barriers to reactant gases, preventing crossover between cells. Several materials have been reported to be used for flow field plates. The material requires several properties:

Chemical compatibility with electrolytes.

Low power losses - low contact resistance, and low bulk resistance.

Impermeability to  $H_2$ .

Ease of fabrication of plate.

Light in weight.

Sufficient strength to withstand handling and high compaction pressures.

Metallic plates can be used in both low and high temperature fuel cells. Ti, and stainless steel plates have been described for use in SPFC's, and Ni-Cr-Fe alloys for solid oxide fuel cells. These plates can be readily machined to millimetre thicknesses. The flow field design can also be machined however, this is a time consuming process. Chemical etching can also be used to form the gas pattern, although the large scale usage of the etchants required (HF for use with Ti, and  $HNO_3$  for use with stainless steels) would be undesirable, and this is also a slow process. Controlling the etching is also a problem, with groove diameter and depth uniformity being difficult to keep within tolerable levels. When the metallic plates are in contact with a corrosive/reactive electrolyte the metals form a thick passive surface oxide layer inhibiting their corrosion, however this leads to higher interfacial resistances and consequently greater power losses in the stack. This has led to the development of alternative, non-metallic materials.

High temperature solid oxide fuel cells can contain plates of lanthanum chromate. Plates can be formed with flow field designs by conventional ceramic forming technology such as dry pressing. However this technology is limited to simple plate designs, and also plates may warp or crack during the high temperature sintering step.

Carbon-based plates have been reported for low temperature fuel cells, in particular solid polymer fuel cells. Carbon is an excellent candidate material for this application, possessing excellent chemical resistance, together with low density and electrical and

thermal conductivity.

Using an exfoliated graphite allows press-moulding of the flow field plates together with embossing of the gas track pattern. A fine grained graphite sheet (GRAFOIL®) has been used to form a flow field plate as detailed in patent no. US 5 521 018, however the impurity level together with low mechanical strength have hindered its development. Resins have been added in order form a plate of higher mechanical strength, as described in patents US 4 301 222 and EP 784 352. However, the presence of an insulating resin reduces the overall conductivity of the plate, leading to greater power losses in the stack. In another invention, US 4 339 322, carbon fibres have also been added to a polymer/graphite material, in order to further improve strength, and conductivity. However, resistivities achieved are still much lower than when using graphite alone.

A fine grained graphite has been machined to shape, although plate thicknesses are of the order  $\frac{1}{4}$ ", due to its low strength. Patent no. US 5 686 199 describes the use of such a material to form flow field plates.

The machining of carbon is a slow process, and costly as tool wear is rapid with these materials. Typically, grooves approximately 10m in length are machined into each plate, using a millimetre size, high velocity milling tool. Hence, specialised equipment is required for this process. Carbon fibre composites are even more abrasive and are more damaging to cutting tools. This has been the reason for avoiding these materials.

There clearly is a need for a rapid, low cost process in which the flow field plates can be fabricated. The current technology that has been described does not provide a cost effective route to forming flow field plates from non-metallic materials.

The present invention describes the novel use of sandblasting for the fabrication of electrochemical cell components. This is a low cost and rapid erosive etching technique that can be used to form fluid flow patterns, fluid entry and exit holes, and o-ring sealing grooves.

The sandblasting method has previously only been applied for a few specified applications. Signmaking and decorative patterning on plastic, stone, wood, ceramic ware, glass, and glass-reinforced plastic, or surface cleaning or roughening treatments utilising this technique are well known. The fine patterns on plasma display apparatus, and magnetic transducing heads can also be formed using sandblasting, detailed in patents EP 0 722 179, and US 4 188 247 respectively.

## [DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT]

### *[Technical Features]*

The present invention involves the use of sandblasting to form fluid flow patterns, fluid entry and exit holes, and o-ring sealing grooves.

The procedure for this involves the use of a patterned mask to cover the face of the workpiece to be modified. This mask can be composed of any material which can withstand the erosive wear caused by sandblasting. A polymeric material is preferred. The mask must be in close contact to the substrate to allow fine detailed patterns to be formed, and this can be achieved by the use of an adhesive. The adhesive must provide sufficient adhesion to hold the mask firmly in place during sandblasting. It is preferred that a contact adhesive is used to fix the mask in the required position, and that it is water soluble to aid the masks removal. The masks employed for this technique can be mounted on a support film, which can be removed from the mask when it has been adhered onto the substrate, by peeling it away.

A technique of forming a photoresist mask is taught in patent no. US 4 764 449, for the decorative marking of glass and wood by sandblasting. The patent teaches the method to form a negative mask of the required design, that exposes only the material to be eroded away. An alternative technique to form an erosion-resistant mask involves the cutting of a vinyl label to shape, as described in patent no. US 4 828 893. Both the photoresist, and vinyl-type masks can be employed with this technique.

The plate can then be exposed to abrasive media in a sandblaster, to form the required pattern. The sandblasting media can be of any ceramic material which has a greater hardness than that of the substrate material being eroded. For carbonaceous materials (with the exception of diamond) it is preferred that fine grained silica, or alumina is used. The grit size used will depend on the detail required in the eroded design. For use to form fluid flow patterns, a grit size of between 180-220 $\mu$ m is preferred.

The blasting pressure used is dependent on the mask material, adhesive used, distance between the gun and the substrate masked surface, and the blast media used. An upper limit is given by the resistance of the mask to the erosive etching, whereas a lower limit is defined by the pressure required to erode the substrate with the abrasive media. This

is preferably measured by the pressure required to produce substantial etching within a reasonable time limit, without damaging the mask, or causing the adhesive to fail.

It may be required that flow tracks are on two sides of a plate, such as that for a bipolar plate. The sandblasting procedure can be performed either simultaneously on both sides, through two separate masks and using two blasting guns, or by carrying out two separate erosive etching steps. The latter method is preferred for this invention. In order to maintain a thin plate, the grooves on opposing faces can be displaced along the plate surface relative to each other. The Figure 1 shows a plate section 3 that has two adhesive 2 and resist 1 layers, which when sandblasted produces the configuration of grooves as shown.

The method for forming holes through a plate, such as those required for fluid entry and exit from the flow tracks has also been developed. The erosive etching required to form a hole through a sample may cause the mask material to fail. However, by eroding grooves aligned on opposing faces of the plates a hole can be formed, as shown in Figure 2.

The area of material that can be erosively etched using a conventional fixed sandblasting gun arrangement, is dependent on the spread of the blasting media. This in turn, is dependent on the distance of the gun from the sample surface, and the size of the gun nozzle. The concentration of blast media hitting the sample surface decreases at higher angles of incidence from the gun nozzle. This can be directly related to a variation of etching of the sample. It is therefore preferred that for samples of surface area approaching or greater than the spread of blast media from the gun, are etched using a dynamic arrangement, whereby the blasting gun and sample surface are moved relative to each other using a two-axis scanning mechanism. This can be achieved by either moving the gun whilst fixing the sample position, fixing the gun position whilst moving the sample, or by the movement of both the gun and the sample. There is no preference to which component is moved. The overall movement relative to each other can trace any pattern that will provide uniform coverage of the sample surface with the blast media. It is preferred that a raster pattern, or a stepped scan pattern is adopted.

The materials that can be used to form flow field plates with this invention include carbon, and other ceramic materials. These may be composite structures, and may include

a polymeric filler.

Carbon fibre composite plates have been used, which possess superior mechanical properties to monoliths, without loss of electrical properties. The inclusion of carbon fibres can also improve the materials thermal conductivity, which can be important if the electrochemical application involves the use of high current densities. The use of high density carbon composites however, is expensive, and so partially densified materials offer greater prospects. Fabrication methods for typical carbon composite materials can be found in the literature. The gas permeability of partially densified materials can be overcome by the densification with a resin. The resin used should preferably be of low viscosity to allow the rapid filling of small pores, and should self-cure. The composition of the resin may be of any polymer formulation that will resist attack by an alkaline or acidic electrolyte. It is preferred that a resin is chosen that can be incorporated under low pressure, which further aids the infiltration of small pores. Immediately after the addition of a resin, the excess should be removed from the surface of the plate. This can be carried out by quickly wiping the surfaces with an absorbent cloth. When the resin has been allowed to cure under the required conditions, the two surfaces which are required for electrical conduction need to be cleaned to expose conductive carbon once again. This can be achieved by a brief surface grinding step. It is preferred that abrasive cloth containing material of 600 mesh size or higher is used. The gas flow field pattern, o-ring grooves, and fluid entry and exit holes can then be formed by sandblasting by the aforementioned method. It has been found, surprisingly, that the rate of erosion of the carbon fibre and matrix does not differ so as affect the final structure of grooves formed in these type of materials.

*[Examples]*

The invention will be further described by way of the following examples. The scope of the present invention, however, is not limited in any way by these practical examples.

*Example 1 (C-C + vinyl mask)*

A graphitised carbon-carbon composite plate of dimensions 50x50x1.2mm was to be prepared with a gas track design on one face. A vinyl-polymer adhesive mask (Avery FasCal film), being a negative image of the required gas track design was pressed firmly onto the composite. A Guyson Blast System with 180-220um silica grit, was used for dry sandblasting the plate. The masked material was held under the sandblasting gun at 4psi for 30s, at a constant distance of 6". The vinyl mask was then peeled off, and then the adhesive washed off the plate using isopropyl alcohol. Track depth was 0.2-0.25mm.

*Example 2 (C-C + photoresist mask)*

A graphitised carbon-carbon composite plate of dimensions 50x50x1.2mm was to be prepared with a gas track design on one face. A photoresist mask (ImagePro Super Film) was developed to form a negative template of the required gas track design. Using a photographic mask of the track design to cover the photoresist (with an underside protective carrier film) and a glass sheet to hold the sheets closely together, it was exposed for 5 minutes to a 18W UV light source, at a distance of 5m away. Afterwards, the film was removed (under yellow light) and then washed under running water for approximately 3minutes, at which time the unexposed resist had been washed away. The resist could then be dried in air, under normal lighting, to form the negative resist template. A liquid contact adhesive (ImagePro Adhesive) was lightly brushed over the composite plate surface, and allowed to dry in air for 10 minutes. The resist mask and carrier film was firmly pressed onto the plate with adhesive, and the carrier film immediately peeled away. The masked material was then blasted using the procedure described in Example 1. The resist mask was then removed, by dissolving the adhesive using warm running water.

### Example 3 (*C-C/epoxy + photoresist mask*)

A graphitised carbon-carbon composite plate of dimensions 50x50x1.2mm was held under low pressure, whilst impregnating with a low viscosity epoxy resin (Struers Specifix-20). Excess resin was removed from the surface of the plate using a paper towel. The plate was then allowed to stand in air, at S.T.P. for at least 8 hours, to allow the resin to cure and harden. A photoresist mask (ImagePro Super Film) was prepared and then applied as in Example 2. The masked material was then blasted using the procedure described in Example 1. The resist mask was then removed, by dissolving the adhesive using warm running water.

### CLAIMS

The application of a photoresist mask to a flow field plate fabrication method.

The application of a vinyl mask to a flow field plate fabrication method.

The technique of sandblasting through a designed mask, to erode a flow field design into a non-metallic plate.

1. The technique of sandblasting through a designed mask, to erode fluid entry and exit holes through a non-metallic plate.
2. The technique of sandblasting through a designed mask, to erode an o-ring groove into a non-metallic plate.
3. The technique of uniformly sandblasting a large sample by the use of a two-axis scanning mechanism, so as to form a raster scan or stepped scan pattern of blasted media over the sample.
4. The use of a carbon fibre-carbon matrix composite material for the fabrication of a flow field plate.



*[Documents Cited]*

**US 5 521 018** - Embossed fluid flow field plate for electrochemical fuel cells (Grafoil - col 10, line 16)

**US 4 301 222** - Separator plate for electrochemical cells (graphite + resin)

**EP 784 352** - Separator for fuel cells of solid polyelectrolyte type and processes of the production thereof (graphite + resin)

**US 5 686 199** - Flow field plate for use in a proton exchange membrane fuel cell (nuclear grade graphite - col 5, line 58)

**US 4 339 322** - Carbon fiber reinforced fluorocarbon-graphite bipolar current collector-separator (carbon fibre polymer matrix composite)

**EP 0 722 179** - Insulator composition, green tape, and method for forming plasma display apparatus barrier-rib (sandblasting designs)

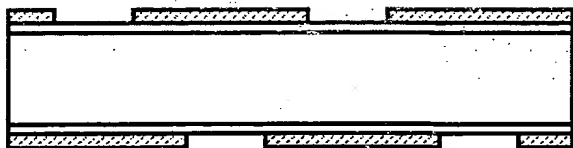
**US 4 188 247** - Manufacture of magnetic transducing heads.

**US 4 764 449** - Adherent sandblast photoresist laminate (uses: col 9, line 60; col 10, line 57)

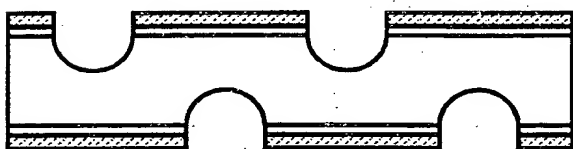
**US 4 828 893** - Sign sandblasting method (vinyl material, col 3, line 45)

**Book: (Fabrication methods for carbon-carbon composites) - ISBN: 0851868045 Shelfmark: HOLBORN: (B) TB 90 Title: Essentials of carbon-carbon composites edited by C. R. Thomas Publisher: Cambridge Royal Society of Chemistry c1993**

[Drawings]



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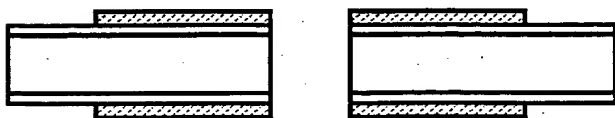


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Fig 1



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Fig 2